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ABSTRACT

Sports-related tool use abilities in children were investigated within a neo-Piagetian framework of development. The object was to establish whether development in the motor domain proceeds in a "stage-like" fashion. A model was developed which suggested how general and precise structural changes might manifest themselves in the sub-domain of tool use. Children's performance was measured on a set of tasks designed to assess the sequence of changes specified by the model of motor development. One hundred children, ranging in age from 4 months to 10 years, were classified to one of ten groups corresponding to the substages of the sensorimotor, inter-relational and dimensional stages. The hypothesis that children's tool use abilities would proceed through a sequence of four substages across three major stages was supported by the data. An analysis of the data gathered from the study supported the notion of vertical structure, i.e., the recycling of structures in development where a clear basis exists for distinguishing major from minor stage transitions. It is suggested that the development of childrens' motor control abilities may in part be explained by cognitive developmental theory. (Author/JD)

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Vertical Structure in the Development of Sports-Related Tool Use in Children

by

Denise Reid

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Abstract

Sports-related tool use abilities in children were investigated within a neo-Piagetian framework of development. Case's (1985) theory of intellectual development provided the conceptual base for the study. The objective was to establish whether development in the motor domain proceeds in a "stage-like" fashion. This aim was addressed by: (1) developing a model which suggested how the general and precise structural changes specified by Case's theory might manifest themselves in the sub-domain of tool use, and (2) measuring children's performance on a set of novel tasks which were designed to assess the sequence of changes specified by the model of motor development. The design of the study was cross-sectional. One hundred children, 50 boys and 50 girls whose ages fell within the range of four months and ten years were tested. According to age, children were classified to one of ten groups corresponding to the substages of the Sensorimotor, Inter-relational and Dimensional stages, as specified by the theory. The hypothesis that children's tool use abilities would proceed through a sequence of four substages across three major stages was supported by the data. Each age group passed items up to the level that had been predicted, but no further. Next, the mean scores of children at each age group were examined for each stage separately to see if they fell on the predicted straight lines. One-way analysis of variances indicated no significant deviation from linearity for any group. These results lend support to the notion of vertical structure, i.e., the recycling of structures in development where a clear basis exists for distinguishing major from minor stage transitions. This study suggests that the development of children's motor control abilities may in part be explained by cognitive developmental theory.

Introduction

Neo-Piagetian theory has been used as a guide in the past by researchers interested in studying the notion that there are general processing abilities on which children can be discriminated, and which can be used for predicting performance on motor tasks. However, the variability found in measurement and differences in tasks have made it difficult to interpret the results.

In the present study, recent neo-Piagetian theory (Case's, 1985) serves as a basis for identifying stages of tool use ability in children, and for developing tasks for measuring this. The notion of "vertical decalage" advanced by Piaget and preserved in neo-Piagetian theory suggests that, at each new stage, children go through a similar progression of structural changes, but at a higher epistemic level. In effect, each stage of development is seen as a new cycle, in what is essentially the same basic structural process. To provide a strong test of vertical structure in development, the present study:
(1) included a range of age groups which spanned the full developmental continuum from birth to ten years of age; and
(2) presented test items which have been designed with the explicit intention of capturing the sort of recursive cycles which Case's theory postulates at different stages of development.

Subjects

The sample for this cross-sectional study consisted of 100 children, 50 boys and 50 girls whose ages fell within the range of four months to ten years. Subjects were voluntary participants drawn at random from a public school and nine day care centres in the city of Toronto. The ten age groups that children were assigned to corresponded to each of the substages of the Sensorimotor, Inter-relational, and Dimensional stages.

Procedures

All subjects (except for two four month olds) were tested individually in the day care or school setting. The motor test was administered in the hypothesized order of structural complexity, until children failed all the items that were two levels above their last successful level. Also, to avoid fatigue, the motor test was presented to children, such that the testing started at items that were one level below the hypothesized level for their age. Testing sessions varied from 30 to 45 minutes per child.

Motor Tasks

According to neo-Piagetian theory, children's ability to acquire and/or learn a novel motor task is constrained by the type of cognitive operations they have available for controlling their movements, and the number of products of these operations which they can place in short-term storage. Hence, an attempt was made to design tool tasks which reflect: (1) increasing levels of structural complexity; and (2) increasing demands on short-term storage space. The pattern, or sequence of changes in motor control suggested in the set of tasks, for each recurring substage of development is characterized as: (1) **uniaxial motor control**, where motor activity occurs along a single axis; (2) **biaxial motor control**, where motor activity occurs along a second axis; and (3) **elaborated-biaxial motor control**, where motor activity occurs about two axes simultaneously.

Sensorimotor Tasks

Operational Consolidation (0 - 4 months)

It was expected that infants of 4 months of age could pass two tasks: (1) reach toward a rattle; (2) visually track a slow rolling ball. Although, both behavioural sequences are different in content, they are similar in their underlying structural form: (1) there is a representation of some object in their environment; (2) there is a representation of the goal of making "contact" with it; (3) there is a representation of a well-integrated motor strategy for doing so, i.e., reaching movement and continuous gaze of the eyes.

Uniaxial Coordination (4 - 8 months)

Children were presented with a box with a peg protruding from it. The task was to move the peg along a single trackway to ring a bell. A second task was also presented: children were asked to grasp a dowel and bring it to their mouth, in a unidirectional fashion. In order to pass these items, children need to coordinate the structure for visually monitoring a moving object with the structure for reaching and grasping an object and that for bringing an object toward self, (all of which are assembled at the previous stage). This unifocal coordination allows children to generate an action-reaction sequence. Hence, they are capable of "uniaxial motor control", i.e., grasp and push/pull peg along trackway to ring bell.

Biaxial Coordination (8 - 13 months)

Children are capable of producing two action-reaction pairs at this stage. Two tasks were presented to assess this capability: (1) moving a peg along an "L" shaped trackway; and (2) striking a bell with a dowel. Children had to grasp a peg and move it along two separate trackways (at right angles to each other), hence they had to maintain "uniaxial control" on the peg while focussing on moving it along a second axis; hence, "biaxial motor control".

Elaborated-Biaxial Coordination (13 - 20 months)

The first task that was designed to assess elaborated or integrated-biaxial coordination was of the same peg-trackway sort as was used in previous stages, however, at this stage, children needed to move the peg along a diagonal pathway to ring the bell. To succeed on this task, it was presumed that children needed to integrate the programs for moving the peg along two different trackways, i.e., sagittal and frontal planes. Two other tasks were also presented at this substage in order to assess the precursors of development of the next stage: (1) push an object (using a dowel) across a table to a target; and (2) catch a rolling ball.

Inter-Relational Tasks

Uniaxial Coordination (20 - 27 months)

The task at this stage was striking a rolling ball with a racket along a sagittal plane to a target. To succeed on this task the hypothesis was that children would require the ability to coordinate two "sensorimotor elaborated-biaxial competencies", i.e., (1) the act of monitoring and catching a rolling ball, with (2) the act of bringing a dowel into contact with a stationary object and controlling its movement. At this stage, this task is thus said to involve a sort of "uniaxial control", since the ball's movement must be controlled with respect to a single axis, (now with a tool, whereas in the previous stage, the child's hand served as the tool).

Biaxial Coordination (27 months - 3 1/2 years)

The task at this substage was monitoring a rolling ball along a sagittal axis (from tester to child), and striking it with a racket, and directing the ball along a frontal axis, i.e., to a target positioned 90 degrees to the child's contralateral side.

Elaborated-Biaxial Coordination (3 1/2 - 5 years)

The task was one where the tester again rolled the ball toward the child, but this time the target was stationed at 45 degrees to their contralateral side, thus requiring they hit the ball along a diagonal path.

Two other tasks were also presented at this level, in order to assess the precursors of stage 3 control. The first task involved the use of the racket to make contact with a ball that was moving through space, rather than rolling along the ground. This capability was presumed to require an on-line coordination between the structure for moving a tool through space in a forward and lateral direction, with the structure for tracking the ball whose position varied along two dimensions, "forward and downward" as it moved towards them. The second precursor task was that of throwing a small ball to a target. This capability was presumed to require control of the movement of the ball along the same sort of "arc" that it traced when the tester threw it, while simultaneously controlling the ball's movement in the sagittal plane.

Dimensional Tasks

The three tasks that were presented at the third level were directly parallel to those that were presented at the previous two levels.

Uniaxial Coordination (5 - 7 years)

Children were presumed to be capable of making contact with a ball that was pitched to them, and of hitting it back with a racket, over a net, in the same direction from which it had come: a task which requires coordinating the two sorts of integrated-biaxial competencies that were hypothesized to emerge at the end of the inter-relational stage, i.e., (1) the act of making contact with a ball, one that is moving through free space; with (2) the act of monitoring the displacement of an object in free space. Hence, children construct a higher-order psychological entity, a "corridor" or free-space axis along which a ball travels and returns.

Biaxial Coordination (7 - 9 years)

Children were presumed to be capable of biaxial tool use in free space. This capability was assessed by pitching them a ball, and asking them to hit it towards a target that was set at eye level, but at a 90 degree angle to their non-dominant side.

Elaborated-Biaxial Coordination (9 - 11 years)

Children at the third substage were presumed to be capable of directing a ball that was pitched toward them, back over a net towards a target that was placed at a 45 degree angle, i.e., along the diagonal. As with the tasks at the previous two stages, control of the ball's movement along the diagonal was presumed to be possible only by integrating the programs for directing the ball along the frontal and sagittal planes.

Scoring

Each item was administered three times. A criterion of 66% was used to determine whether a child passed an item successfully. A score of "1" was assigned if all items in a level were passed. For levels with more than one item, each item passed received a rating of 1/n (n=total number of items at that level). An item was deemed passed, when the child's response met the specific criteria as outlined in the test.

Results

First, the individual pattern of children's performance at each stage was examined, to see if the three different sets of items each formed a Guttman scale. The coefficients of reproducibility were all perfect, indicating that there was no child at any age who passed an item at level X+1, once having failed the item(s) at level X.

Next, the percentage of children passing each item at each age level was examined, to see if the percentages were as predicted, i.e., that each age group passed the items up to the level that had been postulated, but no further. The data did assume the predicted pattern.

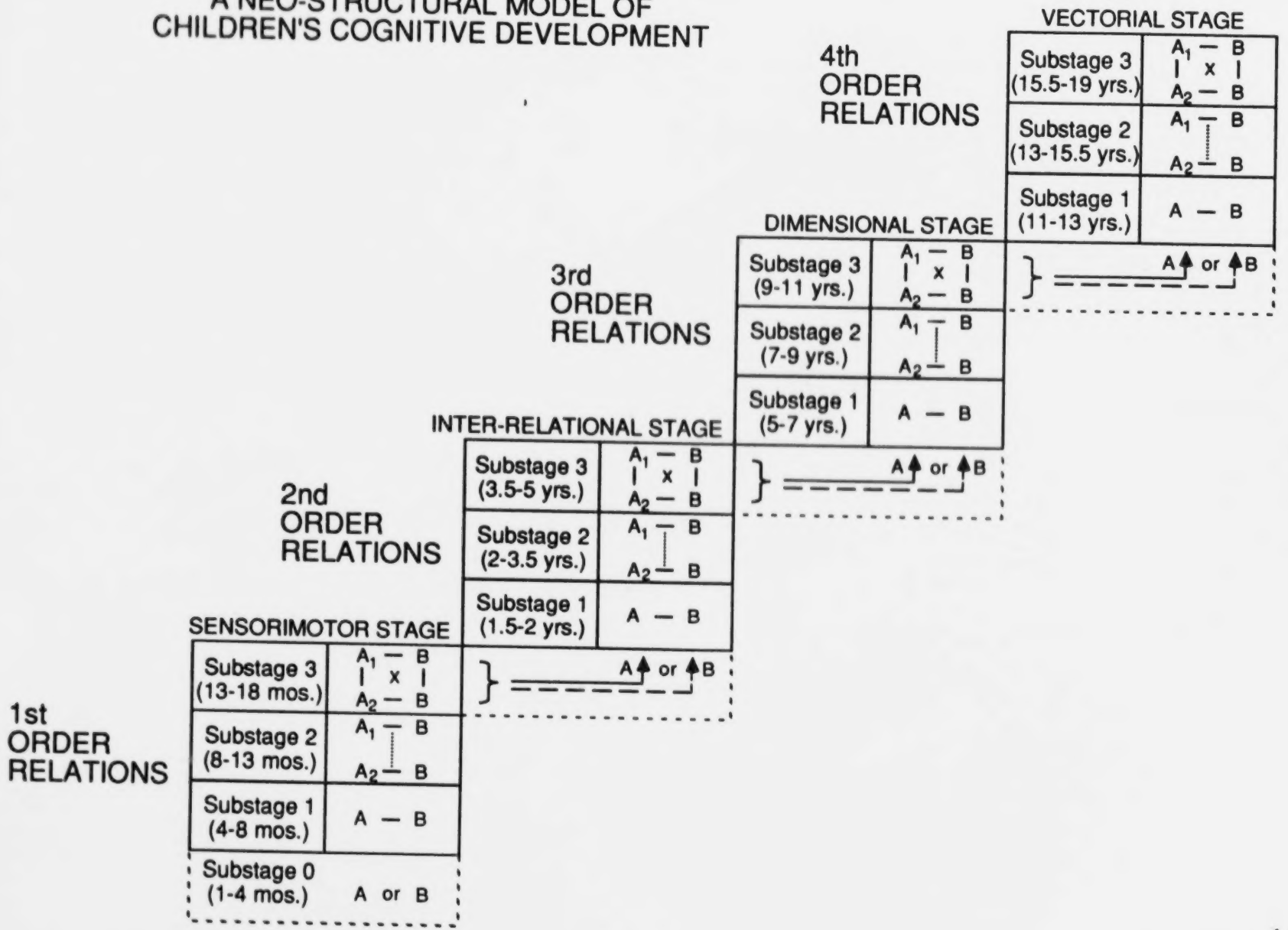
Finally, the mean scores at each stage were examined, to see if they fell on the predicted straight line, i.e., to see if the mean score of subjects who were at the preliminary substage was 1, while the mean scores of the subjects who were at the next three substages were 2, 3, and 4, respectively. The resultant analyses indicated no significant deviation from linearity for any groups.

Conclusions

Neo-Piagetian theory appears to offer a viable explanation for certain aspects of children's motor performance. The unique aspect of Case's theory is its ability to explain recurrent cycles in development, and given an appropriate task analysis, predict the skills for which a child at a given substage and stage will or will not be successful in performing.

It was not assumed that cognitive developmental theory was sufficient to explain all the various aspects of motor development. The role of neuromuscular and biomechanical factors in motor performance, for example, is extremely significant, and cannot be ignored. What was assumed however, was that the same general structural constraints as are present in other domains of human intelligence are also operative in the motor domain. Therefore, if we are to obtain a more complete picture of motor development, these constraints must be somehow taken into consideration.

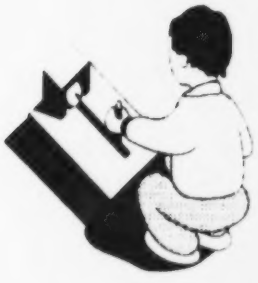
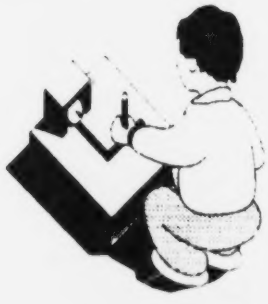
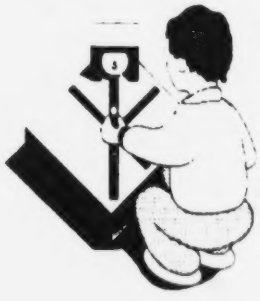
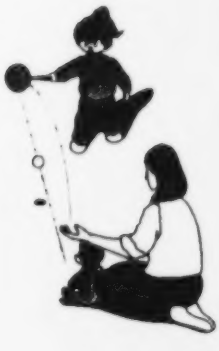
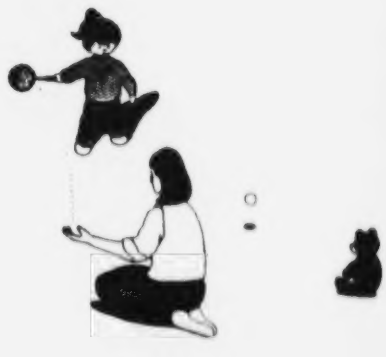
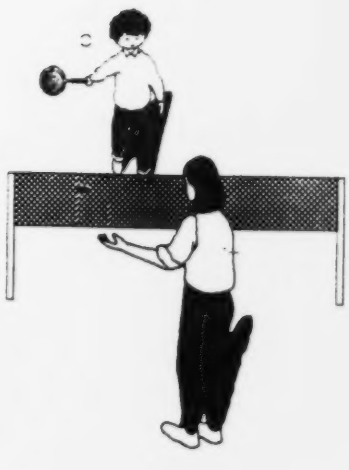
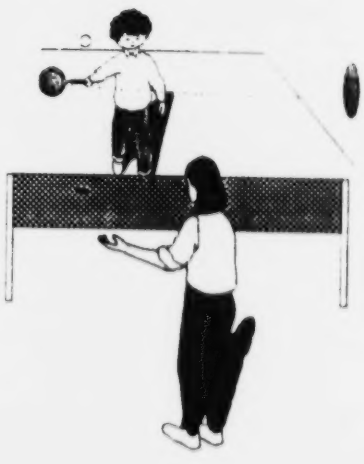
A NEO-STRUCTURAL MODEL OF CHILDREN'S COGNITIVE DEVELOPMENT



DISTRIBUTION OF MEAN AGES ACROSS AGE GROUPS

GROUP (hypothesized age range)	MEAN AGE (SD)	NUMBER OF SUBJECTS
1 (0-4 mos.)	4 mos., 3 wk (0.5)	10
2 (4-8 mos.)	8 mos. (0.7)	10
3 (8-13 mos.)	12 mos., 3 wk (1.0)	10
4 (13-20 mos.)	1 yr., 7 mos. (1.2)	10
5 (20-27 mos.)	2 yr., 2 mos. (1.1)	10
6 (27 mos.-3.5 yrs.)	3 yr., 2 mos. (1.9)	10
7 (3.5-5 yrs.)	4 yr., 7 mos. (2.5)	10
8 (5-7 yrs.)	6 yr., 8 mos. (3.8)	10
9 (7-9 yrs.)	8 yr., 8 mos. (4.0)	10
10 (9-11 yrs.)	10 yr., 6 mos. (1.6)	10

VERTICAL PARALLELS IN THE DEVELOPMENT OF CHILDREN'S TOOL USE ABILITIES

	UNIAXIAL COORDINATION	BIAXIAL COORDINATION	INTEGRATED-BIAXIAL COORDINATION
SENSORIMOTOR STAGE			
	8 MONTHS	12 MONTHS	18 MONTHS
INTER-RELATIONAL STAGE			
	2 YEARS	3 YEARS	4 YEARS
DIMENSIONAL STAGE			
	6 YEARS	8 YEARS	10 YEARS

PERCENTAGE OF SUBJECTS PASSING EACH LEVEL ON THE MOTOR TEST AT EACH STAGE OF DEVELOPMENT

(A) Expected Pattern of Performance at Each Stage

SUBSTAGE	1	2	3	4	+4
0	PASS	FAIL	FAIL	FAIL	FAIL
1	PASS	PASS	FAIL	FAIL	FAIL
2	PASS	PASS	PASS	FAIL	FAIL
3	PASS	PASS	PASS	PASS	FAIL

TASK

(B) Obtained Pattern of Performance (% Succeeding) at Each Stage

(i) Sensorimotor stage

	1	2	3	4	+4
0-4 mos.	100	0	0	0	0
4-8 mos.	100	90	0	0	0
8-13 mos.	100	100	60	0	0
13-20 mos.	100	100	100	100	0

(ii) Inter-relational stage

	1	2	3	4	+4
13-20 mos.	100	0	0	0	0
20-27 mos.	100	70	10	0	0
27-3.5 yrs.	100	100	90	20	0
3.5-5 yrs.	100	100	100	100	10

(iii) Dimensional stage

	1	2	3	4	+4
3.5-5 yrs.	100	0	0	0	0
5-7 yrs.	100	70	0	0	0
7-9 yrs.	100	100	60	0	0
9-11 yrs.	100	100	70	50	0

TASK

PASS = % of Subjects Succeeding on Task > 50%
FAIL = % of Subjects Succeeding on Task < 50%

ACTUAL MEAN SCORES AT THREE DIFFERENT STAGES OF MOTOR DEVELOPMENT, COMPARED TO PREDICTED MEAN SCORES